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LECTURES

ON THE

ANATOMY AND PHYSIOLOGY

OF THE

INTESTINAL CANAL;

MORE ESPECIALLY OF ITS MUCOUS MEMBRANE.

Being the Croonian Lectures *for* 1842, *delivered at the College of Physicians,*

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LECTURES,

&c. &c.

In the Gulstonian Lectures which I had the honour to give two years ago in this College, I took for my subject the anatomy and physiology of the stomach. I examined the form of this organ in the various vertebrate classes, and entered at some length into the investigation of that part of it which, in a physiological point of view, is of the greatest importance—namely, its mucous membrane; and I concluded with a brief statement of the principal facts, touching the influence of this membrane upon digestion.

I now propose to call your attention to the anatomy and physiology of the intestinal canal, more especially with reference to its mucous membrane, as being that portion which determines the physiological office of each division of the canal, and which to us, as practical physicians and pathologists, affords the most numerous objects of interest.

And I trust I need not offer any apology for dwelling upon subjects involving so many anatomical considerations, in lectures before the College of Physicians. No medical body has had, among its fellows and members, anatomists and physiologists of higher reputation—men distinguished as practical physicians, but who, nevertheless, did not neglect to cultivate those sciences which are universally allowed to be the foundation of their art. The names of some of the brightest ornaments of our College are as household words, in the lips of the youngest student of anatomy—and must be handed down to the latest posterity, so long as the science continues to be cultivated. And let it not be said, that in these days, when we profit so much by the abours of our predecessors, and when owing in a great degree to the impulse which they gave to anatomical investigations, medicine has advanced to a high state of improvemen — let it not be said, that now the College of Physicians is less interested in anatomy than formerly—is less anxious to encourage and promote the pursuit of it among its members.

In former days, the College of Physicians was the " nursing mother" of anatomy, and numbered among its fellows the sole teachers of that science. The walls of this building afford ample evidence of this fact, in the numerous portraits of those distinguished men with which they are adorned.

Our greatest boast is of Harvey—respecting whom, Haller says, that his name is, in medicine, second only to that of Hippocrates.

Certain it is, that his discovery of the circulation of the blood was one of the most complete, and its results the most important, that the genius of man ever accomplished. So far as it went, it was perfect: the lapse of more than two centuries has found nothing to add to, or take from, the Harveian doctrine; and having been founded on the certain and immutable basis of anatomy, it must ever continue a leading doctrine of physiology.

Doubtless the singular philosophic caution which Harvey exhibited, in carefully testing the various proofs of his doctrine, during a number of years, before he promulgated it, contributed greatly to its stability. Eight years were spent by this patient observer, in digesting and maturing his ideas;—and let me remark, that the example may not be unseasonably quoted at the present day, when there seems to be more ardour in the

pursuit after novelty, than diligence in the investigation of truth.

Harvey was the first who used the simple microscope in anatomical enquiry. He employed it in the dissection of insects, and in observing the growth of the chick *in ovo*.

Harvey, in a certain degree, anticipated the discovery of auscultation, inasmuch as he availed himself of the assistance of the sense of bearing, to detect the action of the gizzard in birds, as the auscultator uses it, to determine that of the heart. His words are " Falconibus, aquilis, aliisque avibus ex prædâ viventibus, si aurem prope admoveris, dum ventriculus jejunus est, manifestos intus strepitus, lapillorum illuc ingestorum, invicemque collisorum percipias."

We cannot refer to Harvey without likewise alluding to his friend and apologist, the learned Sir George Ent, to whom we are indebted for the publication of Harvey's book " De Generatione Animalium." Ent's dedicatory epistle of this work to the President and Fellows of the College, ought to be read by all who wish fully to appreciate the character of Harvey. Harvey's zeal in the pursuit of truth for its own sake, his singular modesty, his forbearance towards others, and the careful manner in which he conducted his investigations, are brought out in a most interesting manner, in the conversations therein detailed, between him and Ent. One passage I cannot resist quoting, as illustrating the soundness of his views in reference to physiological deduction. " Natura equidem ipsa, (says Harvey) est arcanorum suorum fidissima interpres : quæ, in uno genere, aut pressius, aut obscurius exhibet; ea clarius et patentius in alio explicuit. Nemo sane de partis alicujus usu, sive officio recte determinaverit; qui ejus, in pluribus animalibus, fabricam, situm, annexa vasa, aliaque accidentia non viderit, secumque diligenter pensitaverit."

I need not remark how clearly Harvey has here developed those principles of physiological enquiry, which were subsequently more fully followed out by Haller, Hunter, and Cuvier.

Among the many celebrated anatomists who flourished in the latter half of the seventeenth century, those, who were Fellows of the College of Physicians, shone pre-eminent. Thomas Wharton lived at this time, after whom the duct of the submaxillary gland was named, and the author of the first complete treatise on the glands—his *Adenographia*—which contains excellent descriptions of the glands, and also of the placenta and ovary. In this work, too, Wharton described the mesentery more fully than had been previously done, and showed, that cellular membrane and other parts were interposed between its layers.

Throughout his book, Wharton makes frequent mention of another Fellow of our College, whom Boerhaave calls, " omnium anatomicorum exactissimus," namely, Francis Glisson—a name always associated with the capsule of the liver, which he discovered and described. In addition to his " Anatomia Hepatis," Glisson published a very learned book " De Ventriculo et Intestinis," in which he has fully described these parts, and added many physiological speculations. He first applied the term irritability in the sense in which it is now very commonly used, in reference to muscular fibre, and he seems to have had a very clear notion of what Haller long after described under the name " vis insita." In treating of the Robur fibrarum, he says that it is threefold: " Robur insitum, vitale, et animale ;" " Robur insitum potissimum consistit in fibræ justâ carnositate, et tenacitate :" and he points out that in emaciated animals, wasted by disease, the muscles are deprived of their usual power—that in the athletic, in whom the muscular flesh is luxuriant, there is extraordinary power—and that in the scorbutic, those labouring under syphilis, and the dropsical, the tenacity of the fibres is impaired, and their power greatly weakened. From all which he infers, " Fibras, quò carnosiores, et tenaciores fuerint, eò, cæteris paribus, robustiores esse, et fortiores actiones edere, et e contra macilentiores, et friabiliores fuerint, eò debiliores esse, et citiùs defatigari."

A more clear description of the celebrated Hallerian doctrine of the *vis insita*, I apprehend, could not be given; and, believing as I do, that certain facts recently ascertained have unequivocally proved the validity of that doctrine, I am the more glad on that account to be able to trace it up to a Fellow of the College of Physicians.

Another of the great anatomists of this age was Thomas Willis—the father, if I may so speak, of the anatomy of the nervous system, upon the functions of which, so much light has been thrown by English physiologists.

Willis's fame rests upon his two principal works; the " Cerebri Anatome, et Nervorum Descriptio," and " De Animâ Bentorum."

The name of Willis is associated with the arterial anastomosis situate at the base of the brain, between the carotids and vertebrals, and with the spinal accessory nerves (nervus accessorius Willisii).

Willis first pointed out the anatomical distinctness of the sympathetic nerve from the cerebro-spinal system, although, at the same time, he maintained that a connection existed between them, that the one was engrafted upon the other, *ut frutex super alio frutice*.

No one can peruse the descriptions which this distinguished man has given of the

anatomy of the brain and nerves, without admiring their clearness, and feeling astonished at the knowledge which he had attained. We are too apt to forget, how much of what we now know, was pointed out by him: the arrangement of the encephalic nerves, which is now in common use, and which, for practical purposes is sufficiently good, we owe to him. His chapter on the actions of the brain and the rete mirabile contains many highly interesting facts, which are being continually quoted, and his views as to the use of the rete mirabile accord with those generally adopted by physiologists at the present day.

Nor was Willis less distinguished as a chemist, and a practical physician, than as an anatomist. For many years he enjoyed a considerable practice in London; and it is well known that he was the first to recognize the saccharine condition of the urine in diabetes.

In the preparation for his work on the Brain, Willis derived considerable aid from the pencil of Sir Christopher Wren. He was assisted likewise, in the anatomical part, by another able Fellow of the College, Dr. Richard Lower, celebrated by his "Tractatus de Corde,"—an anatomist of the highest class, who was also distinguished by the experiment which, in conjunction with Dr. King, and on the suggestion of the celebrated architect Wren, he performed on transfusion. Lower was the first to point out that the difference between arterial and venous blood was occasioned by the action of the atmosphere.

At the latter end of the 17th century lived Grew, better known as a vegetable physiologist, and a botanist, than as an anatomist. It appears that he was elected an honorary Fellow of the College on account of his proficiency in natural knowledge. He was curator of the Royal Society, and printed a Catalogue of their Museum.

It is not generally known that Grew had discovered and delineated the glandular patches in the ileum, now so well known by the name of Peyer's glands. He is certainly equally entitled to be considered the discoverer of these glands, as the anatomist whose name they bear; for in an essay, appended to his Catalogue before mentioned, quaintly denominated "The Comparative Anatomy of the Stomach and Guts," he had described and figured these patches with great accuracy in several animals, before Peyer's book reached this country. His delineations are more numerous and much more precise, than those of Peyer; and he seems to have been familiar with the characters of the mucous membrane of the intestines in a great number of animals, and certainly anticipated many points the discovery of which some of his successors assumed to themselves.

Grew first described the sweat-pores on the fingers, the existence of which many subsequent anatomists doubted, but which modern researches have clearly proved to be the orifices of spiral tubes, the aggregate of which forms the great excretory apparatus of the skin.

Clopton Havers also flourished at this time. The name of this anatomist is connected with the vasculo-medullary canals of bone, now much better known than formerly. This discovery of Havers was not at all appreciated by succeeding anatomists. His description, however, was completely confirmed by Monro primus; and subsequently Mr. Howship, with very imperfect means of observation at his command, described the general arrangement of the larger canals in bone, with more accuracy than any preceding observer. Of late years, Deutsch, Minscher, and others, both in this country and abroad, have, by the aid of modern improved microscopes, determined the true nature of these canals; have shown them to exist in vast numbers throughout bone, and to be essentially and intimately concerned in its development, as well as in its nutrition: and thus a later age, provided with better instruments of research, has amply asserted the accuracy of this sagacious observer.

I must not omit to refer here to the physician after whom these lectures have been named. Dr. Croone was an able anatomist, and enjoyed a large share of practice in London. In 1670, he was appointed Lecturer on Anatomy to the Company of Surgeons, and held it till his death. The Croonian Lecture on Muscular Motion, at the Royal Society, was founded by him—a circumstance which alone would associate his name with the theories of muscular action, even had he not written on the subject himself.

At the latter end of this period, Edward Tyson lived, whose monographs upon many subjects of comparative anatomy prove him to have been a most accurate and observing person. His anatomy of a pigmy, of the rattlesnake, of a porpoise, and other papers contained in the Philosophical Transactions, are constantly referred to by comparative anatomists, and contain many original observations which have been fully verified in later times. Tyson assisted Samuel Collins, another Fellow of our College, in his well-known System of Anatomy.

Although the anatomists of the eighteenth century, who were connected with the College of Physicians, were not less numerous than those of the preceding period, they were not, with few exceptions, so distinguished; nor were their names so connected with original

research as those to whom I have alluded. The names of James Douglas, William Hunter and Baillie, are among the most distinguished.

James Douglas was the friend, and, in some measure, the preceptor of Haller, during his residence in this country; and that illustrious man always speaks of him in terms of admiration and affection. He is well known by his "Myographia," and his work on the Peritoneum.

James Douglas was the master of William Hunter, to whose fostering care British anatomy owes so much, and who, were the governments of former days so disposed to favour science as now, would have done much more. Dr. William Hunter's munificent offer made to Lord Bute, the minister of George III., to appropriate £7000, and his museum, to the establishment of an institution for the cultivation of anatomy, was disregarded, and thus his rich collection was lost to this metropolis.

He, however, left behind him a school of anatomists, in Baillie, John Hunter, Cruickshank, and Hewson, who contributed more than others before them, or after them, to raise the character of British anatomy.

The extent to which anatomy has been cultivated in this country, since the time of these distinguished persons, has not been commensurate with our great opportunities, nor does it appear to have been pursued altogether in the spirit of the school of Hunter and of Baillie. The introduction of the French surgical anatomy, or anatomy of regions, although not without considerable utility to the operating surgeon, has, I think, on the whole, been prejudicial to the advancement of that kind of anatomical knowledge, which, as being most conducive to pathology, is best calculated to advance medical science. It has directed attention to investigations of a much easier kind, and thus diverted observers from following out those researches which bear most directly on the functions of organs. If the physiology of the various textures of the body is to be based on a solid foundation, it can only be done by laying that foundation in an accurate knowledge of their intimate structure; and, if anatomists are to derive practical utility from their labours, they must devote themselves to those investigations which are most applicable to general pathology.

I trust that the anatomists of the present day begin to feel, that there is something more demanded of them than the mere knowledge of relative position; nay, that they must pry more deeply into the structure of parts, than they are able to do by the ordinary means at their disposal.

The vast improvement which has of late years taken place in the construction of the microscope, leads us to hope much from the use of that instrument, which is now becoming so general. We are scarcely yet in a position to avail ourselves fully of its aid with benefit in the examination of diseased structures; but when, after the lapse of a few years, we shall have acquired a more precise knowledge of the normal structure, it will be incumbent on us to carry our microscopic inquiries fully into the regions of disease.

It is from microscopic anatomy, normal and morbid, aided by the minute analyses of organic chemistry, and accompanied with the careful observation and record of symptoms during life, that pathology is to derive its future advancement. Nor can any one expect to make material improvements in medical knowledge, who is not competent to conduct his enquiries as a minute anatomist, a minute chemist, and a faithful observer and chronicler of morbid actions.

I must apologize, gentlemen, for having digressed so far from the proper subject of this lecture, and shall now proceed to state the arrangement I propose to adopt.

I shall briefly survey the general disposition of the intestinal canal in the vertebrated classes; in the second place, I shall consider the rough anatomy of its coats, especially of its mucous membrane; thirdly, I shall make some remarks on mucous membranes in general; and fourthly, I shall describe particularly that of the intestinal canal, making such physiological and pathological deductions as may seem to be warranted by the present state of our knowledge.

The division of the intestinal canal, which all anatomists adopt in the human subject, applies very generally throughout the vertebrate series. We find a small intestine, the main function of which consists in the separation of the nutritious from the excrementitious part of the food, and in the absorption of the latter; and a large intestine, in which a still further elaboration and absorption take place, but whose principal office appears to consist in the elimination of the fæcal matter, and its expulsion from the body.

Such being the type of the form of the intestinal canal, we observe much diversity as regards length and width, whether absolutely or relatively to the length of the body, and several peculiarities in the development of certain parts in relation to, or connection with, the intestine, in the various classes, as well as in different orders of the same class.

In fishes the intestinal canal exhibits a very simple conformation. In many fishes it passes very nearly in a straight line through the body: when it does exhibit convolutions, they are few, and very slightly developed. A pyloric valve is generally present, separating the intestine from the stomach: immediately

succeeding to this valve, the intestine generally experiences a dilatation, whence it gradually contracts to its terminal portion, which again becomes dilated. This portion corresponds to the large intestine, and commonly a valvular fold of the mucous membrane constitutes the internal boundary between the two divisions of the canal: it terminates in a cloaca, common to it with the urinary and genital organs.

Immediately below the pylorus there are found, in most fishes, certain tubular processes communicating with the intestine, but ending in blind extremities, that float in the abdominal cavity. These constitute the *appendices pyloricæ*, or pyloric follicles, which seem to represent that extensive salivary apparatus, which is connected with the first portion of the intestinal canal, in all the higher animals. They vary considerably in number as well as in size. In *ammodytes tobianus* there is only one; in *pleuronectes flesus* (the flounder) there are two very short ones, placed opposite each other at different sides of the intestine; there are from ten to thirty in many species of *clupea* and *salmo*; and in the genera *gadus* and *scomber* (the common mackerel, for example) there are as many as two hundred. In some fishes they are simple; in others, they become subdivided or branched at their blind extremities; in others, these branches undergo considerable subdivision; and the resemblance to the glandular formation is enhanced by the fact, that these branches are connected by means of cellular membrane and blood-vessels.

In reptiles, the intestinal canal differs from that in fishes, chiefly in having undergone a slight increase of development. The division into large and small intestine is distinct throughout the class, and an ileo-cæcal valve is often present. In *ophidia*, the small intestine presents numerous short convolutions at acute angles; the large intestine ends in a cloaca. The intestinal canal is longest in the *chelonia*; and next to them, in the crocodiles.

In the *chelonia*, the line of distinction between large and small intestine is not so obvious as in the rest: the muscular coat is remarkable for its great thickness. In *batrachia*, the difference between large and small intestine is very distinct, being chiefly indicated by difference of calibre; and, in frogs, by a circular ileo-cæcal valve.

In birds, the intestinal canal, although longer than in fishes or reptiles, yet retains considerable simplicity of form. It presents much variety in length, and in the number of its convolutions, according to the food and habits of the bird. The most conspicuous portion of the canal is that which is called the duodenum: it succeeds immediately to the gizzard, and has always the form of a long fold, which contains the pancreas in it, and hangs freely into the abdominal cavity. The small intestine, more or less folded in different orders, terminates in a short and somewhat wider large intestine, which ends in a cloaca, as in fishes and reptiles.

At the commencement of the large intestine in birds, which is much wider than the small intestine, are two processes, terminating in thin and free extremities, and communicating with the cavity of the intestine. These are the cæca: they vary considerably as to length from simple papilliform offsets, as in the Soland goose, to processes three feet in length, as in the grouse. In some instances there is only one cæcum.

Connected with the small intestine there is an appendage, which is the remains of the duct of communication between the yolk-bag and the digestive cavity in the chick. In some birds, this appendage, which is devoid of a muscular tunic, is as large or larger than the cæca.

In the mammiferous series, great diversity exists in the form and extent of the intestinal canal. Throughout the class, with a very few exceptions, the commencement of the large intestine is marked by a cæcum, which varies much in size and form: the small intestine is convoluted; and the large intestine ends in the rectum, the cavity of which, except in the monotremata, has no communication with the urinary and genital apparatus.

In the carnivora, insectivora, and the insectivorous genera of bats, we meet instances of the simplest form of the intestine among mammalia. For, not only is it shorter in reference to the length of the body, but its several parts are less fully developed. The small intestine is very slightly convoluted; the cæcum is very short and simple; the large intestine is cylindrical in form, not sacculated, as in man and many herbivora.

In ruminants, solipeds, and pachydermata, the intestinal canal is characterized by great length and wide calibre. In the sheep, the intestine is thirty times the length of the body. In the horse, I have measured the intestine eighty-seven feet and a half; and if we consider the enormous width of the canal, we may form some idea of the immense extent of the intestinal digestive surface. The cæcum is of great size: its capacity in ruminants is about equal to that of their fourth stomach; but, in the horse, the cæcum is capable of containing more than three times as much liquid as the stomach.

The rodentia have in general a very long and convoluted intestinal canal. The small intestine is of small calibre, but considerable length. The cæcum is in most of the genera

of very great size; and, in some, it occupies a large portion of the abdominal cavity. The whole large intestine is cellulated. In omnivorous rodents, as the rat, the cæcum is small; and in one genus, *myoxus* (dormouse), the cæcum is entirely absent; constituting the single exception to the presence of this portion of the canal in the rodent order.

The cetaceous mammalia have an intestinal canal of considerable length. There is, however, a marked difference in length between the intestines of the zoophagous and of the herbivorous whales. In the former division the length of the canal is to that of the body as 11 or 12 to 1; in the latter, as 20, or even 40, to 1. The proper whales have no cæcum: this is the case in the porpoise.

From the brief and very general survey which I have thus taken of the intestinal canal in the vertebrata, it may be gathered that this portion of the digestive tube diminishes in complexity as we descend from mammalia to fishes; that a short and simple intestinal canal is generally co-existent with a diet of animal food; and, on the other hand, that a diet of vegetable food, or a conjoint animal and vegetable diet, requires greater length, and complexity in the form and structure of the intestines. In estimating the extent of the intestinal canal, we should not confine our examination, as is generally done, to a mere external measurement of length, as we should thereby be led to form a very imperfect estimate. Deficiency in length, as measured on the exterior of the intestine, may be supplied by increased width, by a more highly developed state of the villi of the mucous membrane, by numerous folds of that membrane, and the energy of the action of the mucous membrane on the contents of the intestine may be augmented by the greater number of the glands, which pour their secretions on its surface.

Much importance is attached by physiologists, and apparently with good reason, to the size of the cæcum. It is impossible, in the present state of our knowledge, to determine the law which influences its development. It may be stated, however, that there appears to be a direct relation between the development of this intestine and the indigestible nature of the food. In some instances, we find that a very large cæcum compensates for a less capacious stomach, as in the solipeds; and, in these cases, there exists a striking similarity in the forms of these two organs. Anatomy certainly seems to indicate that the function of the cæcum is not dissimilar to that of the stomach, and that in it substances hard of digestion are subjected a second time to a reducing action, resembling that of the stomach.

Lecture II.

The structure of the alimentary canal, which I propose to consider in the present lecture, is essentially the same throughout the vertebrate classes. Its walls are formed by three planes of membrane, connected by intervening layers of cellular tissue. These are the serous, the muscular, and the mucous tunics.

The external tunic, or the *serous*, needs little remark. It is so adapted, that, while it involves the intestine, it yet offers no obstacle to the rapid distension of any portion of it. This is especially conspicuous in the small intestine, where the serous membrane, in its passage from the abdominal wall over the intestinal convolutions, forms a fold of considerable depth, the mesentery, between the layers of which the distended intestine finds a ready passage. The mesocola, or folds connecting the several portions of the colon to the abdominal wall, similarly favour distension, but to a much less degree.

From the peculiar manner in which the serous membrane is reflected upon the intestine, it is evident that it cannot form a complete covering to it. Along the line at which the mesentery in the small intestine, and the mesocolon in the large, adhere to them, a space is left not immediately covered by serous membrane. Here the vessels lie, and give off their branchings, to supply the other tunics.

In two parts of the intestine the serous covering is very imperfect: these are the duodenum in its middle and inferior thirds, the posterior surfaces of which are closely connected, in the greater part of their extent, to the wall of the abdomen; and the rectum, which, to a pretty similar extent, and in a like way, is left uncovered by serous membrane. Hence the operation of paracentesis vesicæ may be performed, in the latter intestine, with impunity as regards the peritoneum.

The descending colon is uncovered posteriorly to a considerable extent; and Amussat has ingeniously taken advantage of this fact to open the intestine here through the posterior wall of the abdomen, with a view to establish an artificial anus, in cases of permanent obstruction in the lower part of the large intestine, or of imperforate anus. The operation has now been sufficiently frequently done, in France and in this country, to demonstrate its practicability; and to show that it may, in some instances, be resorted to with benefit.

The *muscular* tunic of the intestine is developed in two planes: an external one, consisting of longitudinal fibres; and an internal, composed of circular fibres. The different arrangements which these two layers of the muscular coat exhibit, in the large and in the small intestine, constitute a

very manifest feature of distinction, between these two divisions of the canal. In the small intestine each layer is continuous all round the intestine; in the large intestine the longitudinal layer is developed in three bands, which commence at the root of the vermiform appendix of the cæcum, and extend in this form to the rectum, where they become expanded, and form a continuous tunic, as in the small intestine. These bands, being shorter than the intestine to which they are applied, cause numerous puckerings of it in the transverse direction, with bulgings between them, which are the cells of the colon.

In the small intestine, the muscular tunic is most developed in the duodenum; in the large, it is thickest and strongest in the rectum.

I have said that the three planes of membrane which compose the intestinal wall are connected by intervening layers of fine cellular membrane. That which connects the mucous to the muscular tunic is deserving of a special description. It is the submucous cellular tissue, the layer to which Willis gave the name "tunica nervea." It is composed of a very fine areolar tissue, and is the nidus to support the numerous blood-vessels, absorbents, and nerves, which are necessary to the perfect organization of the mucous coat. Its characters are nearly the same throughout the whole intestinal tract; but it seems a little more abundant in the small, than in the large intestine. The seeds of morbid change are generally sown in this tunic, as might be presumed from its more immediate and extensive connection with the blood-vessels, on which the nutritive processes depend.

The *mucous membrane*, or most internal tunic, exceeds the others considerably in length. Hence the necessity of its being thrown into folds, that it may be conveniently packed into a smaller extent of space. Throughout the intestine, in the human subject, these folds assume the transverse direction, and in the latter part of the duodenum and in the jejunum, they exhibit considerable regularity. Here they form valvular processes, projecting more or less into the cavity of the intestine. These folds were denominated *valvulæ conniventes* by Kerckringius, and still retain that name, although they evidently do not perform the office of valves. They are absent, or are very imperfectly developed, in the first portion of the duodenum, and also in the lower part of the ileum. It is worthy of remark, that these *valvulæ conniventes* are peculiar to man. The folds of the mucous membrane of the large intestine likewise assume the transverse direction. They form large partitions between the cells of the colon, and they result from the puckering up of the intestine by the longitudinal fibres, and its constriction at various places by circular fibres shorter than the rest.

The next subject which ought to engage our attention is the minute anatomy of this important tunic of the intestine. Before entering upon the particular description of it, however, I propose to make some observations on the structure of the mucous membranes in general.

Mucous membrane, as has been long known, presents marked analogies, in point of structure, to the skin. It is, like the skin, a covering; the internal integument, while the skin is the external one; it is continuous with the skin at the various orifices—the mouth, anus, prepuce, &c. It is prolonged into the ramifications of the various glands connected with it, as the salivary glands, liver, &c. as the skin is prolonged into the glands connected with it, the sudoriferous and sebaceous glands.

The continuity of these two membranes being clearly established, the one lining the interior of the body, and the other its exterior, it is evident that they must enclose all the other textures, muscles, vessels, &c. between them. These parts are all connected with the deep or attached surfaces of these membranes: the vessels, nerves, lymphatics, reach each by its adherent surface. Hence the free surface of each may be said to constitute the exterior of the body; that is to say, all matters connected with the cavity of the intestine, or the free surface of the skin, may be regarded as outside the body. Nor is it difficult to conceive that the one membrane, if placed in the position of the other, might perform its functions, and *vice versâ*, and by a stretch of imagination, one might suppose that, were it possible to turn a man inside out, the mucous membrane would perform the function of skin; or the outer integument that of mucous membrane. As, indeed, Trembley affirmed took place in the polype: when it was turned inside out, its external covering, now become internal, took on itself the secreting and digestive action; and it often happens that a long protruded portion of mucous membrane, exposed to the action of the air, acquires much of the appearance, and many of the characters of skin.

A careful examination of the intimate structure of each of these membranes, and a comparison of them in the various situations in which they occur, not only completely establish the analogy between skin and mucous membrane, but demonstrate their continuity in a manner hitherto unknown to anatomists, and prove them to be different parts of one and the same membranous expanse, modified according to the office specially assigned to each. It is true that Bichat and others had regarded these two membranes in this light, but since

their views were based on the indications of a coarse anatomy, and since, from their not having availed themselves of the microscope, they were unable to obtain a minute anatomical analysis, they failed in demonstrating, what they had so happily surmised.

In the description I am now about to give, I have great pleasure in acknowledging the assistance I have derived from the researches of my valued friend, Mr. Bowman, whose excellent investigation of the minute anatomy of voluntary muscles is now well known to anatomists*. In the present account, however, I shall chiefly follow my own observations.

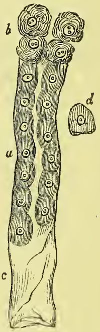
I have said that mucous membrane lines the interior of the body, and that it permeates the ramifications of the elementary tubes of which the glands are composed. It, indeed, forms the walls of those tubes, and to analyse its structure, we cannot do better than examine one of them with high powers in the microscope. The kidney affords a favourable opportunity for this purpose, and in its *tubuli uriniferi*, we shall find the elementary constituents of mucous membrane. Let me here remark, that all examinations of this kind ought to be made on parts quite in the fresh state, for the cohesion of the minute elements of this texture disappears very soon after their vitality†.

It had been ascertained by Henle, that the wall of a uriniferous tube is composed of two elements—a transparent membrane, and an epithelial covering; and to Mr. Bowman is due the merit of having shown, that these elementary parts exist, wherever true mucous membrane is found, and that skin is similarly compounded.

The primary, and most essential of these elements is the transparent membrane. It affords, perhaps, the simplest and most beautiful example of a membranous expansion which can be met with in the body. It forms the basis, on which the epithelial element is deposited; and to it the mucous membrane owes whatever cohesive power, strength, or other physical property, it possesses. Hence Mr. Bowman has given it the appropriate name of *basement membrane;* and by this name I shall designate it in the remainder of these lectures. The basement membrane is homogeneous, perfectly transparent; the highest powers of the microscope cannot detect in it any definite arrangement of particles. The Germans would call it structureless (*strukturlos*). We are not without examples of the occurrence of a similar texture elsewhere in the body. The transparent tube, that envelops the fleshy elements of the primitive fasciculus of voluntary muscle, presents precisely the same characters. The wall of the nerve tubule, which contains the soft neurine, is equally transparent and structureless: so, also, are the posterior layer of the cornea (*membrana Demoursii* of the French), and the capsule of the crystalline lens.

The basement membrane does not admit vessels into its texture. These ramify on its deep or parenchymal surface, and are supported by the submucous cellular tissue, very distinct in the intestinal canal, or, as in certain glands, by a soft cytoblastema, which seems to be derived from recently effused *liguor sanguinis*, and from which probably the basement membrane and the epithelium derive their nutrition and growth.

FIG. 1.



Human Kidney Tubule, magnified 300 *diameters.*

c, basement membrane, from which the epithelium has been detached.

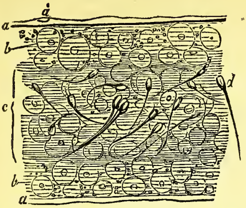
The basement membrane may be readily seen in other parts besides the kidney tubes. In the tubuli seminiferi of the testicle it is highly developed, and of considerable thickness (fig. 2). In the glands whose tubes present vesicular terminations, it is also highly developed, as in the pancreas or salivary glands (fig. 3). In the Meibomian glands, it may be very distinctly seen; also in the tubes of the stomach, especially towards their deep, or adherent extremity*.

* Since this lecture was delivered, Mr. Bowman has published an able article, on Mucous Membrane, in the Cyclopædia of Anatomy and Physiology, Part XXIII.; to which the reader may refer for details beyond the scope of this lecture.

† The structure of mucous membrane has recently been described by a distinguished anatomist, from preparations made by prolonged maceration! I have no doubt that, if M. Flourens would examine, with the microscope, the layers which he has so skilfully dissected, he would find that they are composed of areolar tissue.

* I am satisfied that Wasmann is incorrect in describing the dark part of the mucous mem-

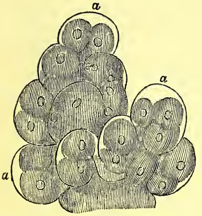
Fig. 2.



Portion of Tubuli Testis of Guinea Pig, magnified 300 *diameters.*

a a, basement membrane. *b b*, epithelium.

Fig. 3.



Terminal Vesicles of Pancreas of Dog.

a a, basement membrane.

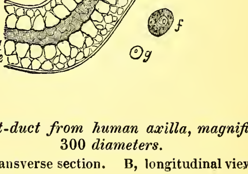
Upon the basement membrane, the epithelium is formed, and is deposited in one or more layers. It is entirely composed of nucleated cells, varying much in size and shape, according to the manner in which they are packed, and the disposition of the mucous membrane, of which they form a part. To the consideration of this highly important element we shall return by and by.

A minute examination of the skin will enable us to see that it is constituted in a precisely similar manner to mucous membrane. According to the account generally given by anatomists, skin consists virtually of two layers, chorion and epidermis, the rete mucosum, which is counted a third layer, being now acknowledged on all hands to be only the recently formed epidermic cells, immediately applied to the papillary surface of the chorion. The chorion is described as a fibro-cellular texture, on the free surface of which, papillæ are developed.

A vertical section of the skin (and it is best to select a specimen from a situation where the papillæ are developed), when examined by a high power in the microscope, shews three distinct layers: first, epidermis, deposited in a series of lamellæ, and distinguishable by the scale-like character of its component particles; second, a thin, extremely delicate, homogeneous, and transparent membrane, in every respect precisely similar to the basement membrane just described; and, thirdly, a layer of interlacing fibres, in which the elementary fibres of areolar tissue, and of the yellow elastic tissue, abound, and which are destined to connect the skin to the adjacent textures, and to support the vessels which ramify in great numbers among them. This last layer is nothing else than the *chorion* of anatomists; but it is evident that the true elements of the skin are the layers superficial to it, the basement membrane and the epidermis, as in mucous membranes; and that the so-called chorion bears the same relation to those elements of the skin, that the submucous cellular tissue does, to those of the internal integument: in short, that the chorion is the more superficial part of the *subcutaneous cellular tissue*, upon which the basement membrane is expanded, and in which the nutrient and absorbent vessels, and the nerves of the skin, ramify.

And strong confirmation of this view of the anatomy is derived from the fact that these elements are found in the various appendages of the skin, which may be regarded as true offsets from it. In the sudoriferous glands, which exist in vast numbers throughout the whole surface of the external integument, the basement tissue may be seen forming the wall of the convoluted tube, of which the gland is composed. A highly magnified view of one of these sweat-ducts, from the pencil of Mr. Bowman, is given in fig. 4; and here the basement tissue may be seen, as a fine line, *a*,

Fig. 4.



Sweat-duct from human axilla, magnified 300 *diameters.*

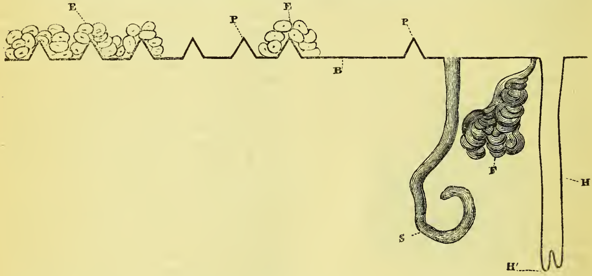
A, transverse section. B, longitudinal view.

brane in the pig, as composed solely of epithelial cells. Those columns are, as throughout the stomach, contained in tubes of basement membrane, which I have seen several times.

forming the exterior of the tube, and the globular particles of epidermis, *b*, constituting its innermost layer. The vessels from which the secretion is elaborated, ramify around the external surface of the basement tissue. The same disposition of epidermic particles within, basement tissue external, and vessels surrounding, may be seen in the sebaceous glands, and in the follicles from which the hairs spring.

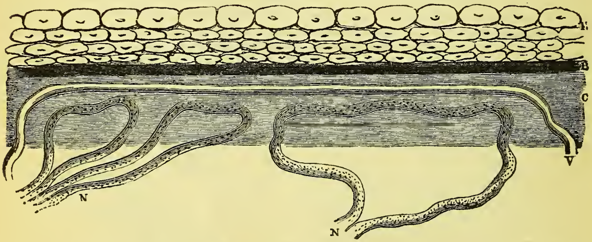
I have given a rough plan of the anatomical disposition of these constituents of the skin in fig. 5, where the dark line, B, represents the basement tissue, elevated at certain intervals into conical projections to form the papillary structure of the skin, and involuted into the form of a spiral tube, S, the sudoriferous gland, or into that of a sac with vesicular bulgings, F, the sebaceous gland, or to form a hair follicle, H, with a papilla, H′, raised from its blind extremity, from which the hair grows. The epidermis, E, covers this basement membrane, to a variable extent, wherever it exists, and beneath it lies the subcutaneous tissue, the chorion.

FIG. 5.—*Diagram showing the basement membrane and epidermis of the skin, and its involutions to form the sweat-duct, the sebaceous glands, and hair follicle.*



Let me refer to another diagram illustrative of the structure of mucous membrane, which may be advantageously contrasted with that of skin to prove their identity of composition (Fig. 6). Here the dark line, B, represents the basement tissue; E, the epithelial covering; and C, the submucous cellular tissue, containing V, vessels, and N, nerves.

FIG. 6.—*Diagram of simple expanded mucous membrane.*



The relation of the blood-vessels and nerves to the true skin and mucous membrane, is worthy of observation. It may appear startling to those who are accustomed only to the coarse anatomy of these textures, that I should class them as *extra vascular*. It seems, at first, impossible to believe this of tissues which have so long been regarded as the most highly vascular textures in the body; of which preparation after preparation is preserved in the various museums of anatomy, to exhibit their extreme vascularity, and about which the skill of a Malpighi, a Ruysch, and Leiberkühn, were so long employed. It is evident from the description I have given of these membranes, and the diagrams I have referred to, that the ele-

ments of them are not *penetrated* by vessels, and that therefore they must lie exterior to the vascular plexus by which they are supplied, and a comparison of the measurement of the basement tissue will shew that blood-vessels *cannot* penetrate its substance. In the tubes of the testicle the basement membrane measures in thickness about $\frac{1}{10000}$ of an inch, but the smallest capillary vessel has a diameter of rather more than double that size. That these membranes require, for their nutrition and their other functions, a capillary plexus of great extent, is perfectly true; and that the seat of that plexus is the submucous or subcutaneous tissue, and not the mucous or cutaneous, I conceive to be abundantly proved by the observations I have above detailed. And the extreme tenuity of the proper elements of the skin and mucous membrane will sufficiently explain, why the vessels appear so superficial, when an injected specimen of these textures is examined.

The extent to which we are now able, through the improvement of the microscope, to carry our anatomical analysis, by the aid of high powers, will serve to remove much of the vagueness of our views as to the relation of vessels to the elements of tissues. I have no difficulty in stating that not only the ultimate but the proximate elements, of all the tissues are *extra vascular;* and that the tissues hitherto admitted by most anatomists, as of this kind, are mere products of a process of secretion. Cuticle, for example, nails, hairs, epithelium, horn, are secreted by the tissue on which they rest, and are separated from the vessels by that tissue. In mucous membrane and skin, however, the vessels come in immediate contact with the basement membrane, but do not penetrate it. In muscle, the elementary part, the primitive fascicle, composed of a sheath containing the sarcous elements, is not penetrated by the nutrient vessels: they ramify in the interval between the fascicles. In the analogous tissue, nerve, the nerve-tubes containing neurine, do not admit vessels: they are extra-vascular. In bone the proximate elements are cylinders, the axis of each of which is pierced by a canal: the vessels are lodged in the Haversian canals, and the osseous elements, nourished by the corpuscular canals, which are not blood-vessels, but which doubtless imbibe the nutrient fluid from the blood-vessels of the Haversian canals, are deposited around and between these canals. So it is with teeth: the dentine does not admit blood-vessels, but derives its nutrition from the vessels of the pulp and of the osseous cortex of the fang. In fat, again, the adipose membrane is as free from vessels as the sarcolemma of muscle, or the tubular membrane of nerve; but the vessels play around the vesicles which they form, as vascular circles.

Blood-vessels are every where surrounded and supported, more especially when they are destined for the nutritive process, by a soft blastema or elementary texture, either truly cellular, in the strict sense of that term, or areolar or fibrous. This is, no doubt, the seat of those changes upon which the growth and nutrition of the tissues depend. The blastema is itself the result, of an effusion of the liquor sanguinis, through the walls of the capillaries; and it is not improbable, that the same series of phenomena (the formation of cytoblasts, of cells, and the ultimate transmutation of these cells into the elementary parts of the tissues) takes place in it, as Schwann has shown to occur in the primary development of the various textures.

And the views I have expressed, respecting the relation of blood-vessels to the tissues, are quite in accordance with what we know to take place, at the early formation of the embryo. The vascular system we know to be developed on a plane, intermediate to those, in which the various tissues appear. The so-called serous lamina, with which the development of the skin, nerves, muscles, &c. is connected, and the mucous layer, which gives rise to the internal integument, must therefore enclose the vessels between them; the vessels are consequently connected with the parenchymal surface of each layer; and this relation they continue to preserve in adult life.

I would propose the following subdivision of the tissues, founded upon the relation of the vascular system to them:—

1. Those tissues which are merely secreted products, and which are therefore separated by an intervening membrane from the vessels, *e. g.* epidermis, epithelium, hair, nails, hoof, horn.

2. Tissues whose proximate elements are in contact with vessels, but are not penetrated by them; *e. g.* muscle, nerve, mucous and serous membranes, skin, bone, cartilage, fibrous membrane.

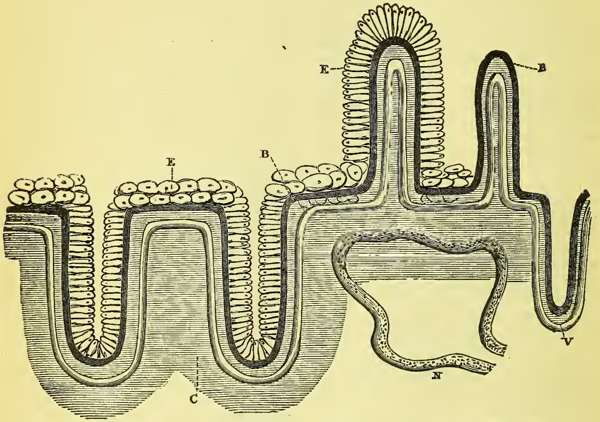
3. Tissues which accompany and surround vessels, forming a blastema for the nutrition of other tissues, or a support for the vessels themselves, or adapted as a connecting link with other textures; and in this class I would enumerate the soft gelatiniform cellular membrane; and the areolar tissue.

But to resume the proper subject of my lecture.

The plan which I have given in the diagram, of mucous membrane, represents its simplest disposition, as a mere expanse. We find it, however, much more extensively arranged, in a complex manner, so as to obtain a great extent of surface, with less occupancy of space. It is then involuted,

so as to form tubes, simple or branched, or mere depressions; or villi projecting into the cavity of the membrane in a manner analogous to that shown in the diagram of skin. This complex form of mucous membrane is represented by a diagram, fig. 7. All the elements of the mucous membrane will be found in these involutions, whether

FIG. 7.—*Diagram of an involuted Mucous Membrane, to shew the continuation of its elements into the foldings.*



E, epithelium; B, basement membrane; C, submucous tissue; V, vessels; N, nerve.

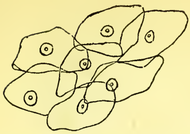
they form simple follicles, or villi, as in the diagram, or more complicated branchings, as in the ramifications of the secreting tubes or glands. (This point, however, has not yet been satisfactorily made out as regards the ultimate branchings of the hepatic duct.) The apparent thickness, which the mucous membrane exhibits in some situations, is owing to these involutions being closely packed together, in a direction perpendicular to the submucous cellular tissue, as is manifest in that of the stomach, and intestinal canal. In other situations, as in glands, the involutions of the mucous membrane are kept very much apart, by the intervening vascular ramifications, and their accompanying blastema, or cellulo-fibrous tissue. To judge of the real thickness of an involuted mucous membrane, we must carefully examine thin vertical sections of it under high powers.

Of epithelium.—The epithelium constitutes a highly interesting and important element of mucous membrane; whether we regard its immense quantity, or the rapidity and extent with which it is being continually thrown off, and reproduced. It is now known that the presence of this product is a characteristic of all secreting surfaces, serous, as well as mucous and cutaneous; and the doctrine is daily gaining ground, that by it the separation of, at least, the organic elements of the secretion are effected. We know that the epidermic scales are continually separating to be succeeded by new ones: so it is with the epithelial particles, whether in glands or on surfaces. The mucus which is formed on the surface of all mucous membranes is no more than the *debris* of those epithelial particles, combined with moisture, which have been pushed off by a new deposit on the surface of the basement membrane.

The newly deposited epithelium is generally, if not always, globular or spheroidal in its form; but it afterwards becomes modified in its shape by pressure, and the mode of packing.

When the surface is flat and expanded, the old epithelium assumes a flattened form, and is that variety which Henle calls *pflaster epithelium*, consisting of scales, generally polygonal, containing a nucleus, and resembling very closely the scales of the cuticle, which are formed and flattened in a precisely similar way (fig. 8).

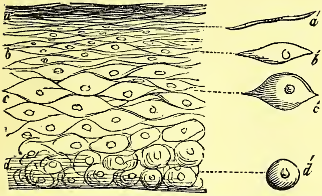
FIG. 8.



Epithelium scales detached from the surface of the uvula, magnified 300 *diameters.*

In fig. 8 some epithelium particles of the scaly kind are shown; and in fig. 9 is an illustration of the manner in which these particles become changed from the spherical to the scaly form as they lose their water, and are compressed by the newly-deposited layer beneath.

FIG. 9.



Vertical section of epithelium of the mouth, showing successive layers, and the flattening of the superficial ones.

a a, superficial scales. *d d*, recently formed ones.

In most of the glands the epithelium retains its globular or spheroidal form, owing probably to the absence of compression and evaporation; but in the kidney, where the water excreted at the distal extremities of the tubes flows over, and compresses the newly deposited epithelium, the particles appear slightly flattened.

On the involuted mucous membrane of the intestines and stomach, and on that of the uterus and of the lungs, we find a third variety of epithelium particles, to which Henle has given the name *cylindrical*, but which I prefer to designate *columnar*. Each particle tapers at its adherent, and presents an expanded polygonal base at its free extremity: when viewed attached to a surface, these particles appear like a number of little pillars or columns placed perpendicularly to it. They may be best seen in the villi of the intestine, or in Lieberkühn's follicles; and their mode of arrangement is explained by the diagram of involuted mucous membrane (fig. 7.)

It is difficult to account for the peculiar form of this variety of epithelium: I am disposed to believe that it may be explained by the particles being arranged round a cylindrical surface in a radiating manner, and being therefore subjected chiefly to a lateral pressure.

Although I have stated that epithelium may be regarded as a secreted product, the cell-like structure of its particles shows, that its mode of formation is similar to that of the more complex tissues; and, therefore, that it cannot be regarded at first merely as a collection of excreted lifeless particles. It is, at its first formation, part and parcel of the living organism, and its particles have their appropriate vital endowments. And if the morphological character of the tissue were not sufficient to prove this, it is abundantly evident from the singular phenomenon which is always associated with it: I allude to the rapid movement of the vibratile cilia, which grow from it, generally from the columnar

FIG. 10.

Ciliated epithelium particles.

a, From human membrana tympana.
b, From bronchial membrane.

variety, and which seem to derive their motor impulse, from the vital power of the particle, to which they adhere. A few of these particles, from the frog's mouth, will continue to exhibit the motion of cilia for many hours together under the microscope, provided they are kept moist, although all connection with the surface, from which they sprang, has been destroyed.

In my next lecture I shall apply these general observations to the particular anatomy of the intestinal mucous membrane.

LECTURE III.

THE mucous membrane of the intestinal canal is of that nature which, in my last lecture, I described as the involuted kind. It presents this character throughout its whole tract, from the pylorus to the anus.

By its involutions it forms tubes, which are arranged, side by side, and vertically to the submucous areolar tissue: their orifices are directed to the cavity of the intestine, so that they can pour into it the mucus which they secrete. When, therefore, a vertical section of the intestinal mucous

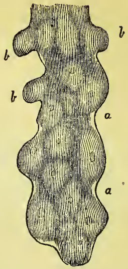
membrane, *in any part of its course*, is examined, it will be found to be composed of these vertical tubes, which are merely involutions or foldings of the membrane, containing, as I pointed out in my last lecture, the elements of that texture, its basement membrane, and epithelium, and nourished by the blood-vessels brought to their parenchymal surface by the subjacent areolar tissue. These tubes afford an example of the simplest form of involution of the mucous membrane; but occasionally we see a slight complication, from many of them being bifurcated at their blind extremities.

The diameter of these tubes is pretty uniform throughout their whole depth; and it is this circumstance which constitutes the main difference between the tubes of the intestine and those of the stomach. The latter are irregular, and bulging towards their blind extremities; the former are uniformly cylindrical throughout. The tubes of the stomach, at least in most of the higher vertebrata, open into the bottoms of cells; those of the intestine have, each, a distinct opening into its cavity. If, then, a piece of intestinal mucous membrane be viewed on its free surface, it is found to present an innumerable multitude of minute foramina, which are the orifices of these tubes.

These tubes are commonly described under the name, *follicles of Lieberkühn;* they were well known to Brunner, who flourished several years earlier than the last named anatomist, and are accurately represented by him in the second plate of his book on the Duodenum; they were also known to Leuwenhoek, who, however, mistook them for muscles. It is only very lately that we have become acquainted with their true structure: the use of high powers, and an improved mode of illumination (I allude to the achromatic condenser), have revealed to us the large quantity of columnar epithelium which enters into their composition*.

The peculiar arrangement of these tubes gives to the mucous membrane its apparent thickness. The tubes of the small intestine are longer than those of the large; consequently the mucous membrane of the former appears thicker than that of the latter. In

FIG. 1.



Stomach tube of dog at its blind extremity, showing its bulgings and globular epithelium.

a, Basement membrane.
b, Globular epithelium, inclosed in a bulging portion of the tube.

all respects of structure, the tubes of the two divisions of the intestine are precisely the same.

It must be evident to the most superficial observation how admirably this arrangement is adapted to obtain a great extent of mucous surface within a limited amount of space. Are Lieberkühn's follicles the seat of a special secretion; or are they merely disposed with reference to obtaining the greatest possible amount of surface? It seems evident, that they must be the principal source of the mucus which is found on the intestinal surface; but how that fluid differs from the secretion of the other intestinal glands, we have at present no means of determining.

Besides these foldings into tubes, the mucous membrane of the small intestine presents other minute foldings, which are precisely like the follicles of Lieberkühn, turned inside out. These processes are termed *villi;* they project from the free surface of the mucous membrane into the cavity of the intestine, and are admirably adapted to become implanted, like so many little roots, in any semifluid or fluid material which may fill the intestine. Hence the comparison of these little processes to the spongioles of plants is not without foundation from anatomy.

The structure of a villus is precisely the same as that of an everted Lieberkühn's follicle; that is to say, it is composed of columnar epithelium, placed vertically to the basement membrane, and adherent to it by the sharp extremities of the epithelial columns. The cavity of the villus is occupied by vessels, lacteals, nerves, and areolar tissue; that of the Lieberkühn's follicle contains

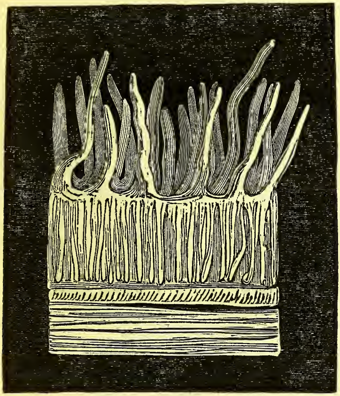
* In my Gulstonian Lectures for 1839, I stated my inability to find columnar epithelium in the stomach tubes, and thus appeared to impugn the accuracy of Henle, who, by his method of scraping, ascertained its presence in that organ. Henle did not, however, say where it was to be found. I have since ascertained that it exists in the walls of the tubes, but not throughout their whole extent. Towards the blind extremities of the tubes the epithelium is globular (fig. 1): in the rest of their extent it is columnar: on the free surface of the mucous membrane it is scaly. In Lieberkühn's follicles the epithelium is columnar throughout.

only the secreted product, and opens, as we have already seen, into the intestinal cavity.

An accurate idea of the relation which the villi bear to Lieberkühn's follicles may be obtained from examining the diagram of involuted mucous membrane, which I shewed in my last lecture : fig. 7, p. 14.

In fig. 2 is shewn a vertical section of a portion of the mucous membrane of the dog, in which the relative position of these two kinds of folding of the mucous membrane is well displayed.

Fig. 2.



Section of the mucous membrane of small intestine in the dog, showing villi and Lieberkühn's follicles.

Villi exist only on the mucous membrane of the *small intestine;* the term *villous membrane*, although frequently used synonymously with mucous membrane, is correctly applicable only to that of the small intestine. The villi are developed gradually at the upper part of the duodenum. They originate in an elongation of the partitions between the cells, which, precisely similar to those of the stomach, occupy the mucous surface of the upper part of the duodenum. These partitions gradually become more and more elongated, forming villous folds, and the apertures between them gradually contract.

Villi present many variations in shape and in length. In man their outline is triangular, and their length varies from 1-36th to 1-48th of an inch. In the dog and cat they form long filiform processes. In the turkey they form large lamelliform folds.

The villi are most numerous where the most active process of absorption is going on ; that is, in the inferior third of the duodenum, and in the upper part of the jejunum. Their vessels are very numerous ; and in a well-injected specimen a beautiful capillary plexus may be seen beneath the whole surface of each villus. This plexus is supplied by a central artery, which passes through the axis of the villus, and, at its free extremity, breaks up into the beautiful capillary plexus which is visible on its surface ; from this plexus several small veins carry off the blood (fig. 3).

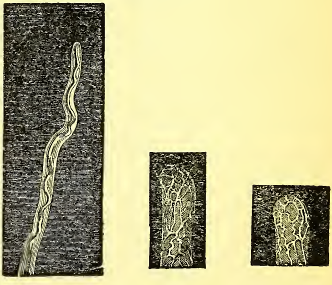
Krause delineates the lacteals as forming a plexus in each villus ; upon this point I cannot give an opinion. It is quite certain, however, that pores, or orifices for absorption, do not exist, as Cruikshank and others thought. I regret to add, that I am unable to specify the precise relation which the nerves bear to the villi.

There seems every reason to regard these organs as specially endowed with the absorbent function. Their anatomical constitution admirably fits them for this function ; they exist in that part of the intestine where absorption is most active : during chylification we see them turgid with chyle. It is true that absorption of chyle takes place without them, as in the large intestine, and in those animals that have them not.

The mucous membrane of the large intestine is quite the same as that of the small, the villi having been abstracted.

Glands of the intestine.—Besides Lieberkühn's follicles, there are certain special glands existing in different parts of the intestinal tract. Some of these are frequently the seat of disease, and therefore it is very necessary that the physician should have an accurate knowledge of their nature and position.

Fig. 3.



C B A

Injected villi of a dog.

A B, Free extremity, shewing the capillary plexus.
C, The central artery alone injected.

We may enumerate three classes of glands:—

1. *Brunn's* or *Brunner's glands.* I prefer to give to these glands the name *duodenal*, for they strictly belong to this portion of intestine, and form one of its principal characters. They were discovered and described by J. C. Brunn in 1686. The best mode of displaying them is that which he advises, namely, to slit up the intestine; pin it, with its mucous membrane downwards, under water; and then dissect off the serous and muscular coats. The glands will be found arranged in the submucous coat, where they present the appearance of numerous small white bodies or grains, scattered throughout the tunic, very numerous towards the pylorus, and gradually diminishing in number, and ceasing altogether at the end of the duodenum. They precisely resemble the elementary grains of a salivary gland, spread out on an expanded surface, instead of being collected into a mass. They commence abruptly, at the duodenal side of the pyloric valve, but cease gradually, becoming less and less numerous, as the duodenum advances. They vary a good deal, both in size and in numbers, in different individuals; and in a few cases I have had great difficulty in finding them, owing to their being extremely small. Like other glands of the intestine, they seem to me to waste and almost entirely disappear in many old persons. These glands belong specially to the duodenum; and the appropriateness of the name *duodenal* is enhanced by the fact, that no other part of the intestine ever exhibits any structures like them.

Such is the description of them in man. They are distinct, but occupy a small space, not more than an inch beyond the pylorus, in the cat, dog, and rabbit. In the horse they are larger than in any animal I have examined them in; in him they form several layers surrounding the intestine, each layer containing grains of a different size, the larger ones being nearest the mucous membrane.

The structure of these bodies is precisely the same as that of the elements of salivary glands, or the conglomerate gland of the older anatomists. Its ultimate secreting element consists of bunches of vesicles, as may be seen in fig. 4, which is a diagram to show their structure, as I have observed it under a high power, and their relation to the intestine. The vesicles C have ducts emerging from them, which, by coalescing, form large ones, and these pass through the submucous tissue, and open on the surface of the mucous membrane, between Lieberkühn's follicles, or by becoming continuous with them.

2. The second class of intestinal glands have received the name "*solitary glands*,"

Fig. 4.

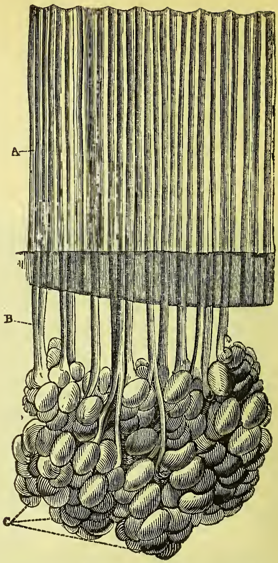


Diagram of a magnified view of Brunner's glands.

A, Lieberkühn's follicles.
B, Ducts of the glands.
C, Terminal vesicles of the glands.

glandulæ solitariæ. Several anatomists and physicians confound them most erroneously with Brunner's glands; from which, however, they differ very materially in structure, in position, in liability to disease.

The solitary glands are scattered throughout the small intestine, and are most numerous below the duodenum; they also exist in considerable numbers in the large intestine, especially in the cæcum and vermiform appendix. If you examine the cæcum of the dog, you obtain an excellent example of them on a large scale. They are simple vesicular bodies, resembling in section a Dutch bottle, wide at their blind extremity, and tapering to the surface of the mucous membrane, on which they open by a very fine orifice, not easily seen in the human subject, especially in the glands of the small intestine. Each gland is deposited in the midst of Lieberkühn's follicles, and therefore appears surrounded by a zone of the orifices of these tubes. When filled with mucus, or any other material, they appear

like little spherical bodies in the submucous coat, and cause a prominence of the mucous coat towards the cavity of the intestine. On the other hand, when empty, they are so flaccid and thin, that they may readily elude the observation even of an experienced anatomist.

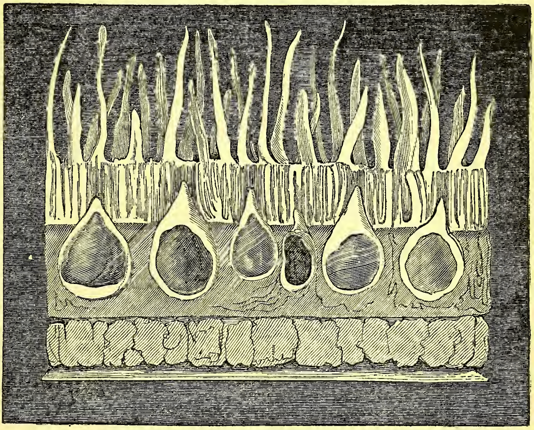
3. The *agminate glands—glandulæ agminatæ s. aggregatæ*—are familiarly known by the name, *glands of Peyer*. They are elaborately described by Peyer, and also by Wepfer; but they were previously known in this country, and had been described and figured in a great number of animals by Dr. Grew.

These are aggregations of papilliform bodies, which, as regards structure, are vesicles, tapering to a pointed extremity, precisely like the solitary glands. Each papilliform body is lodged in a cup-like cavity, and may, in this respect, be compared to the calciform papillæ situate at the back part of the tongue. They are collected together into, generally oval, sometimes circular, patches; which are always on or towards the free border of the intestine, never on its mesenteric border—and therefore, in proceeding to examine them, you must open the intestine along its mesenteric border. It is always adviseable to examine these glands under water, and, in washing them, you should not let a large stream fall upon them, but the adhering mucus should be removed as gently and as carefully as possible. The papilliform vesicles, which constitute the essential part of the glands, are so delicate, especially in the human subject, that the slightest violence is apt to destroy them.

These patches may first be seen at a distance of about seven or eight feet from the pylorus: here they are very small, roundish—about a quarter of an inch in diameter, frequently very indistinct, so that, without great care, they may be readily overlooked. From this place to the junction of the ileum with the cæcum they are found at intervals; the length of the patches for the most part increasing, as you proceed, towards the large intestine. In number, the patches vary from 17 to 32, and in size I have found them to measure, the upper ones a quarter of an inch to one inch in their long diameter—the lower ones two to four inches—and the short diameter from a quarter to half an inch.

These glands are very variously developed in different individuals. They are most distinct in young subjects, and gradually become less prominent with the advance of age. In this respect there is a similarity with the duodenal glands. In the lower animals they are very distinct, and appear to have much more firmness, and greater cohesion. In the dog, cat, lion, the papillæ are large; in fig. 5 is a view of a section of one of the patches;

FIG. 5.



Vertical section of a patch of Peyer's glands in the dog.

and here the papilliform bodies may be very distinctly seen projecting between the tubules of Lieberkühn, and the villi. In the rabbit the glands are very distinct, as well as the cup-like sheaths which embrace them.

Have these papilliform vesicles orifices at

their apices? My own opinion would lead me to answer this question in the affirmative; but Henle and others maintain that they are closed cells, and that they burst, in order to discharge their secretions. It would be exceedingly difficult to distinguish a small orifice at the apex of one of these bodies, and I cannot confidently say that I have seen one: but in the solitary glands, between which and their bodies I can see no material difference of structure, the orifices are very distinct in the large intestine; and, although they are not so obvious in the small, yet I have frequently seen them there also; and in the dog and cat, and sometimes in man, they are distinctly visible to the naked eye. Henle, Purkinje, Schwann, Wasmann, and others, believing that these closed cells not only exist in mucous surfaces, but likewise form the terminal vesicles of the salivary and other glands, have advanced the doctrine that the first part of the act of excretion consists in the giving way, or bursting, of the wall of the cell, and the consequent evacuation of its contents. And it was supposed that Wasmann's description of the dark part of the gastric mucous membrane in the pig, as composed of columns of closed cells, gave great confirmation to these views. I stated, however, in my last lecture, that the cells described by Wasmann were contained in tubes of basement membrane precisely similar, although somewhat larger and more complicated, than the tubes of the digestive stomach of all the mammalia.

What are the functions of these three kinds of intestinal glands? We do not possess any facts which would enable us to give a satisfactory answer to this question. The glands of the duodenum are so like the pancreas in structure, they are so strictly confined to the upper part of the intestine, with which that gland is also connected, that we cannot resist the conclusion that their function is of the same nature, and that they form part of the salivary apparatus of the upper portion of the intestinal canal.

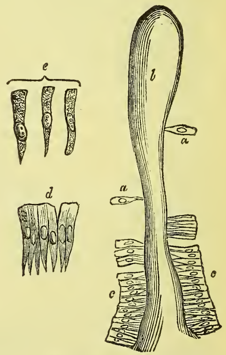
In like manner we find connected with the oral part of the digestive tube two distinct portions of the glandular apparatus; one collected to form solid organs, the *salivary glands;* and the other diffused over the sub-mucous cellular tissue of the mouth, the *buccal glands*, forming a glandular layer very analogous to the glands of Brunner. Until we know more, however, of the change which saliva is calculated to produce in the ingesta, we cannot form any opinion of the office of the fluids secreted by what I would call *the salivary apparatus of the intestine.*

The solitary glands, and those of Peyer, so closely approximate each other in structure, that they probably are not very dissimilar in function. Do they secrete the odoriferous principle which the feculent matters acquire in their passage through the intestine? We know that some of the cutaneous glands secrete a material, which is often quite as offensive to the olfactories, as the most fœtid discharge from the bowels.

A most interesting application of the knowledge of minute anatomy to the investigation of disease was made by Boehm in his examination of the intestinal canal in cholera.

He found that the rice-water dejections were full of columnar epithelium. This was derived from the surface of the mucous membrane, which became stripped of its epithelium, as the skin would have its cuticle separated, after the application of a blister. These parts presented an appearance as if they had been deprived of the epithelium by mechanical scraping. All the regions of the mucous membrane did not suffer equally. The stomach rarely experienced any change; but the principal seat of the mischief were the ileum and the jejunum: the separation of epithelium becoming less the nearer you approached the stomach. All the involutions of the mucous membrane became affected: the tubes of Lieberkühn and the villi—the latter were swollen, elongated; their vessels much injected; their epithelial sheath so much destroyed, that only a few columns here and there adhered to them, presenting an appearance similar to that which my friend Mr. Bowman has depicted in Fig. 6, to show the effect of mechanical disturbance on the villi of the dog.

Fig. 6.



Villus of the ileum of a dog, with the epithelium partially detached.

Nor is the destruction limited to a scraping off of epithelium. The villi, according to Boehm, become split up into fibres, and

the follicles undergo the same disintegration; and so rapid is the work of disorganization, that he states that he had known instances in which the worst of these changes had occurred, in patients who began to complain in the morning, and were dead at noon.

And, as might be anticipated, Peyer's and the solitary glands partake in the general scraping: the vesicular bodies forming the glands were opened and destroyed: the submucous tissue infiltrated and thickened.

These effects of cholera upon the mucous membrane might be contrasted with the ravages of an extensive scald upon the skin; and the state of collapse, which is induced by the stripping of either integument, shows that similar constitutional effects follow similar lesions in both.

It is very remarkable to how great an extent Brunner's glands enjoy immunity from disease; and, in this respect, these glands present an additional point of resemblance to the pancreas, which is very rarely the seat of morbid action.

Disease of Peyer's and of the solitary glands forms a most formidable complication of two of the most serious maladies the physician has to deal with; namely, typhus fever and tubercular phthisis.

The typhoid poison has a remarkable tendency to affect the patches of Peyer's and the solitary glands; so much so as to obtain for it abroad the appellation *typhoid abdominalis.* This tendency was first noticed by an English physician, Sir John Pringle, although the priority of observation is generally attributed to Rœderer and Wagler.

In a large proportion of cases of typhus, these glands are more or less altered in the ileum and in the cæcum. The subjacent tissue is infiltrated and thickened: ulcers are formed. When a Peyer's patch is ulcerated, the ulcer retains the oval shape, and has an elevated edge and hardened base.

The ulcers which result from disease of the solitary glands are small and circular. Frequently the ulcerative process attacks the coats of the intestine in succession, causing perforation.

In phthisis, similar ulcerations occur, but from a different cause. The tubercular matter is deposited in these glands, or in the subjacent areolar tissue. The ulceration is the result of the effort to eliminate this matter, as takes place in the lungs. The seat of ulceration is always in the glands; the intervening portions being only affected so far as the ulcerative process may have spread into them from the glands.

So far as my experience goes, and from what I have learned by reading of the experience of others, I believe it may be stated positively, that Brunner's glands are never affected either in phthisis or in typhus.

Let me conclude this lecture with a few observations on the innervation of the intestinal canal.

The greatest portion of the intestinal canal is supplied with nerves from one source only, namely, from the great sympathetic, from its thoracic and abdominal portions, by the splanchnic nerve and the plexuses into which it divides.

When portions of the sympathetic are examined by the microscope, they are found to consist of the same nerve-tubes, with contained white matter, as are seen in the nerves of animal life. But these tubes seem few, compared with the bulk of the nerves; and it is evident that the size of the nerve is provided for by a large quantity of areolar tissue. This is apparent from the immense number of the minute fibres of this tissue which are seen under the microscope.

After much careful examination of those nerves, I have never succeeded in detecting any other elements in them than those I have named. The peculiar organic fibres described by Remak, Retzius, Müller, and others, are, I believe, fibres of areolar tissue*, and take no part in the manifestation of nervous action.

Whence do these nerve-tubes come? The greatest part unquestionably from the cerebro-spinal centres — the axis of all the nerves in the body: and this, I think, is very manifest when we examine the extensive and numerous connections of the sympathetic with the cerebral and spinal nerves. It is now well known that such a connection exists between the anterior and the posterior root of each spinal nerve: now the connecting branches are of that size, that they must contain several nerve-tubes, and when the great number of the sources, whence these nerve-tubes come, is taken into the account, and when we consider the small size of the trunk and branches of the sympathetic, it cannot be supposed that much room is left for fibres not immediately connected with the brain or spinal cord. If such fibres exist, they must originate or terminate in the ganglia.

In the ganglia, the nerve-tubes are brought into relation with grey matter; and here, again, we find no material difference of the structure from that of the ganglia of animal life. A more abundant areolar tissue in the former might enable an experienced observer to distinguish the one from the other; but I know of no other feature of difference.

But is there no peculiarity in the nerve-tube of the sympathetic? Undoubtedly there is, and that a very remarkable one; not of structure, but of relation; not anatomical,

* I have very lately found that these fibres disappear under the influence of acetic acid, just as those of areolar tissue do, —a strong confirmation of the opinion advanced in the text.

but physiological: and this will be best understood if we trace the branch of communication with the posterior spinal root. This branch, as doubtless consisting of afferent fibres, derives them from the intestinal surface; proceeding from this point, we trace them to the plexus surrounding the intestinal arteries: here they intermingle with grey matter; thence they pass to the semilunar ganglion, where they again mix with grey matter; from that they pass by the splanchnic nerve to certain intercostal ganglia, to mix a third time with grey matter, and a fourth time, in passing from these latter into the ganglia of the posterior roots.

Here, then, the remarkable feature in these nerve tubes is the frequent communication which they form with grey matter. And doubtless this must modify, to a certain extent, their vital endowments. Nor is it improbable that their apparent independence of the sensorium results from this; and that the frequent intervention of grey matter between the central and peripheral portions of the nerve-tubes may intercept the afferent influence of one class of tubes, and afford an independent efferent power to the others, and so, by a frequent communication or connexion between those two kinds of animal matter, the co-operation of which is necessary to the development of nervous power, provision will be made for the due regulation of the parts submitted to their influence, without necessarily involving either the brain or spinal cord. Thus the actions of parts supplied by the sympathetic system alone *may* go on indefinitely without the cognizance of the sensorium, by the exercise of nervous power, developed through the reciprocal influence of the two elementary forms of nervous matter, extraneous to the cerebro-spinal axis.

Such is, doubtless, the mode in which the actions of the intestinal canal are produced. The peculiar arrangement of its muscular coat is admirably adapted to facilitate that succession of contractions and relaxations by which one portion of the canal expels what the succeeding one is prepared to receive. The peristaltic action of the intestine seems more the necessary result of their anatomical arrangement, and of the great length of their muscles, rendering it difficult that the stimulus to action should reach them all at the same instant, than of any peculiarity in the nervous influence.

It seems most probable that its muscular contractions are always due to a reflected stimulus; and that moderate distension, by the natural contents of the intestinal tube, is the usual and normal excitant. Hence, too great distension, or total vacuity of the canal, or any portion of it, are equally prejudicial to its actions; the one, by paralysing the muscular coat; the other, through the absence of the wonted stimulus. I doubt much the correctness of the common notion of a continual rhythmical action of the intestinal canal. It is true, when you first open an animal that has been recently killed, you see all the intestines in active vermiform movement, but this is owing to the sudden contact of the air with their surface. For after a time the active movement subsides, and may be excited again by stimulating the surface of the intestine, or its nerves. Drastic purgatives are powerful excitors of the intestinal movements, acting through the afferent nerves, whose influence is reflected through the efferent ones.

Anatomy proves, as I have already stated, that a considerable proportion of the nerve-tubes of the sympathetic, if not all of them, are connected with the brain and spinal cord. Physiological experiments and daily observation, both of healthy and morbid actions, confirm this fact. Valentin has found that, by irritating the dorsal and lumbar spinal nerves, which communicate with the intestinal portion of the sympathetic, increased peristaltic action may be produced. The pain which is felt from the presence of any irritating substance in the alimentary canal affords abundant proof that the nerves of the intestines communicate with the brain. And, in paraplegia from diseased spinal cord, the patient suffers from irregular flatulent distensions of different parts of the intestinal canal, consequent upon the want of tone and power in its muscular coat.

The lower part of the intestine is not only supplied with nerves from the sympathetic, but also more directly from the spinal cord by the branches of the sacral plexus. The object of this seems to be, to associate its actions with those of the abdominal muscles, whose co-operation is necessary for the act of defecation. This act is excited by the stimulus of distension in the rectum, which, acting through the ganglionic nerves, stimulates its muscular coat, and, through the sacral nerves, affects the nerves of the abdominal muscles, and causes them to contract.

The time which has been allotted for these lectures obliges me to stop here; but I cannot conclude without thanking my audience for their kind and patient attention to a rapid and imperfect review of a most important and interesting subject, and expressing my regret, that it has not been treated in a manner commensurate with its magnitude and practical value*.

* This lecture was delivered Feb. 18, 1842.

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